SCIENCE

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THE SUN'S MOTION IN SPACE.[1]

SCIENCE needed two thousand years to disentangle the earth's orbital movement from the revolutions of the other planets, and the incomparably more arduous problem of distinguishing the solar share in the confused multitude of stellar displacements first presented itself as possibly tractable little more than a century ago. In the lack for it as yet of a definite solution there is, then, no ground for surprise, but much for satisfaction in the large measure of success attending the strenuous attacks of which it has so often been made the object.

Approximately correct knowledge as to the direction and velocity of the sun's translation is indispensable to a profitable study of sidereal construction; but, apart from some acquaintance with the nature of sidereal construction, it is difficult, if not impossible, of attainment. One, in fact, presupposes the other. To separate a common element of motion from the heterogeneous shiftings upon the sphere of three or four thousand stars is a task practicable only under certain conditions. To begin with, the proper motions investigated must be established with *general* exactitude. The errors inevitably affecting them must be such as pretty nearly, in the total upshot, to neutralize one another. For should they run mainly in one direction, the result will be falsified in a degree enormously disproportionate to their magnitude. The adoption, for instance, of a system of declinations as much as 1″ of arc astray, might displace to the extent of 10° north or south the point fixed upon as the apex of the sun's way (see L. Boss, Astr. Jour., No. 213). Risks on this score, however, will become less formidable, with the further advance of practical astronomy along a track definable as an asymptote to the curve of ideal perfection.

Besides this obstacle to be overcome, there is another which it will soon be possible to evade. Hitherto, inquiries into the solar movement have been hampered by the necessity for preliminary assumptions of some kind as to the relative distances of classes of stars. But all such assumptions, especially when applied to selected lists, are highly insecure; and any fabric reared upon them must be considered to stand upon treacherous ground. The spectrographic method, however, here fortunately comes into play. "Proper motions" are only angular velocities. They tell nothing as to the value of the perspective element they may be supposed to include, or as to the real rate of going of the bodies they are attributed to, until the size of the sphere upon which they are measured has been otherwise ascertained. But the displacements of lines in stellar spectra give directly the actual velocities relative to the earth of the observed stars. The question of their distances is, therefore, at once eliminated. Now the radial component of stellar motion is mixed up, precisely in the same way as the tangential component, with the solar movement; and since complete knowledge of it, in a sufficient number of cases, is rapidly becoming accessible, while knowledge of tangential velocity must for a long time remain partial or uncertain, the advantage of replacing the discussion of proper motions by that of motions in line of sight is obvious and immediate. And the admirable work carried on at Potsdam during the last three years will soon afford the means of doing so in the first, if only a preliminary investigation of the solar translation based upon measurements of photographed stellar spectra.

The difficulties, then, caused either by inaccuracies in star-catalogues or by ignorance of star-distances, may be overcome; but there is a third, impossible at present to be surmounted, and not without misgiving to be passed by. All inquiries upon the subject of the advance of our system through space start with an hypothesis most unlikely to be true. The method uniformly adopted in them — and no other is available — is to treat the *inherent* motions of the stars (their so-called *motus peculiares*) as pursued indifferently in all directions. The steady drift extricable from them by rules founded upon the science of probabilities is presumed to be solar motion visually transferred to them in proportions varying with their remoteness in space, and their situations on the sphere. If this presumption be in any degree baseless, the result of the inquiry is *pro tanto* falsified. Unless the deviations from the parallactic line of the stellar motions balance one another on the whole, their discussion may easily be as fruitless as that of observations tainted with systematic errors. It is scarcely, however, doubtful that law, and not chance, governs the sidereal revolutions. The point open to question is whether the workings of law may not be so exceedingly intricate as to produce a grand sum total of results which, from the geometrical side, may justifiably be regarded as casual.

The search for evidence of a general plan in the wanderings of the stars over the face of the sky has so far proved fruitless. Local concert can be traced, but no widely-diffused preference for one direction over any other makes itself definitely felt. Some regard, nevertheless, *must* be paid by them to the plane of the Milky Way, since it is altogether incredible that the actual construction of the heavens is without dependence upon the method of their revolutions.

The apparent anomaly vanishes upon the consideration of the profundities of space and time in which the fundamental design of the sidereal universe lies buried. Its composition out of an indefinite number of partial systems is more than probable; but the inconceivable leisureliness with which their mutual relations develop renders the harmony of those relations inappreciable by short-lived terrestrial denizens. "Proper motions," if this be so, are of a subordinate kind; they are indexes simply to the mechanism of particular aggregations, and have no definable connection with the mechanism of the whole. No considerable error may then be involved in treating them, for purposes of calculation, as indifferently directed; and the elicited solar movement may genuinely represent the displacement of our system relative to its more immediate stellar environment. This is perhaps the utmost to be hoped for until sidereal astronomy has reached another stadium of progress, unless, indeed, effect should be given to Clerk Maxwell's suggestion for deriving

[1] A. M. Clerke in Nature of Oct. 15.

the absolute longitude of the solar apex from observations of the eclipses of Jupiter's satellites (Proc. Roy. Soc., vol. xxx. p. 109). But this is far from likely.

In the first place, the revolutions of the Jovian system cannot be predicted with anything like the required accuracy. In the second place, there is no certainty that the postulated phenomena have any real existence. If, however, it be safe to assume that the solar system, cutting its way through space, virtually raises an ethereal counter-current, and if it be further granted that light travels faster with than against such a current, then indeed it becomes speculatively possible, through slight alternate accelerations and retardations of eclipses taking place respectively ahead of and in the wake of the sun, to determine his absolute path in space as projected upon the ecliptic. That is to say, the longitude of the apex could be deduced together with the resolved part of the solar velocity; the latitude of the apex, as well as the component of velocity perpendicular to the plane of the ecliptic, remaining, however, unknown.

The beaten track, meanwhile, has conducted two recent inquiries to results of some interest. The chief aim of each was the detection of systematic peculiarities in the motions of stellar assemblages after the subtraction from them of their common perspective element. By varying the materials and method of analysis, Professor Lewis Boss, director of the Albany Observatory, hopes that corresponding variations in the upshot may betray a significant character. Thus, if stars selected on different principles give notably and consistently different results, the cause of the difference may with some show of reason be supposed to reside in specialities of movement appertaining to the several groups. Professor Boss broke ground in this direction by investigating 284 proper motions, few of which had been similarly employed before (Astr. Jour., No. 213). They were all taken from an equatorial zone 4° 20′ in breadth, with a mean declination of + 3°, observed at Albany for the catalogue of the Astronomische Gesellschaft, and furnished data accordingly for a virtually independent research of a somewhat distinctive kind. It was carried out to three separate conclusions. Setting aside five stars with secular movements ranging above 100″, Professor Boss divided the 279 left available into two sets — one of 135 stars brighter, the other of 144 stars fainter, than the eighth magnitude. The first collection gave for the goal of solar translation a point about 4° north of α Lyræ, in R.A. 280°, Decl. + 43°; the second, one some thirty-seven minutes of time to the west of δ Cygni, in R.A. 286°, Decl. + 45°. For a third and final solution, twenty-six stars moving 40″–100″ were rejected, and the remaining 253 classed in a single series. The upshot of their discussion was to shift the apex of movement to R.A. 289°, Decl. + 51°. So far as the difference from the previous pair of results is capable of interpretation, it would seem to imply a predominant set towards the north-east of the twenty-six swifter motions subsequently dismissed as prejudicial, but in truth the data employed were not accurate enough to warrant so definite an inference. The Albany proper motions, as Professor Boss was careful to explain, depend for the most part upon the right ascensions of Bessel's and Lalande's zones, and are hence subject to large errors. Their study must be regarded as suggestive rather than decisive.

A better quality and a larger quantity of material was disposed of by the latest and perhaps the most laborious investigator of this intricate problem. M. Oscar Stumpe of Bonn (Astr. Nach., Nos. 2999, 3000) took his stars, to the number of 1,054, from various quarters, if chiefly from Auwers's and Argelander's lists, critically testing, however, the movement attributed to each of not less than 16″ a century. This he fixed as the limit of secure determination, unless for stars observed with exceptional constancy and care. His discussion of them is instructive in more ways than one. Adopting (the additional computative burden imposed by it notwithstanding) Schönfeld's modification of Airy's formulæ, he introduced into his equations a fifth unknown quantity expressive of a possible stellar drift in galactic longitude. A negative result was obtained. No symptom came to light of "rotation" in the plane of the Milky Way.

M. Stumpe's intrepid industry was further shown in his disregard of customary "scamping" subterfuges. Expedients for abbreviation vainly spread their allurements; every one of his 2,108 equations was separately and resolutely solved. A more important innovation was his substitution of proper motion for magnitude as a criterion of remoteness. Dividing his stars on this principle into four groups, he obtained an apex for the sun's translation corresponding to each as follows: —

Group.	Number of included stars.	Proper motion. ″ ″	Apex.			
				°		°
I.	551	0.16 to 0.32	R.A.	287.4	Decl.	+ 42
II.	340	0.32 to 0.64	"	279.7	"	40.5
III.	105	0.64 to 1.28	"	287.9	"	32.1
IV.	58	1 28 and upwards	"	285.2	"	30.4

Here, again, we find a marked and progressive descent of the apex towards the equator with the increasing swiftness of the objects serving for its determination, leading to the suspicion that the most northerly may be the most genuine position, because the one least affected by stellar individualities of movement. By nearly all recent investigations, moreover, the solar *point de mire* has been placed considerably further to the east and nearer to the Milky Way than seemed admissible to their predecessors, so that the constellation Lyra may now be said to have a stronger claim than Hercules to include it; and the necessity has almost disappeared for attributing to the solar orbit a high inclination to the medial galactic plane.

From both the Albany and the Bonn discussions, there emerged with singular clearness a highly significant relation. The mean magnitudes of the two groups into which Professor Boss divided his 279 stars, were respectively 6.6 and 8.6, the corresponding mean proper motions 21.9″ and 20.9″. In other words, a set of stars on the whole six times brighter than another set owned a scarcely larger sum-total of apparent displacement. And that this approximate equality of movement really denoted approximate equality of mean distance was made manifest by the further circumstance that the secular journey of the sun proved to subtend nearly the same angle whichever of the groups was made the standpoint for its survey. Indeed, the fainter collection actually gave the larger angle (13.73″ as against 12.39″), and so far an indication that the stars composing it were, on an average, nearer to the earth than the much brighter ones considered apart.

A result similar in character was reached by M. Stumpe. Between the mobility of his star groups and the values derived from them for the angular movement of the sun the conformity proved so close as materially to strengthen the inference that apparent movement measures real distance The mean brilliancy of his classified stars seemed, on the contrary, quite independent of their mobility. Indeed, its changes tended in an opposite direction. The mean magntude of the slowest group was 6.0, of the swiftest 6.5, of the

intermediate pair 6.7 and 6.1. And these are not isolated facts. Comparisons of the same kind, and leading to identical conclusions, were made by Professor Eastman at Washington in 1889 (Phil. Society Bulletin, vol. xi., p. 143; Proceedings Amer. Association, 1889, p. 71).

What meaning can we attribute to them? Uncritically considered, they seem to assert two things, one reasonable, the other palpably absurd. The first — that the average angular velocity of the stars varies inversely with their distance from ourselves — few will be disposed to doubt; the second — that their average apparent lustre has nothing to do with greater or less remoteness — few will be disposed to admit. But, in order to interpret truly, well-ascertained if unexpected relationships, we must remember that the sensibly moving stars used to determine the solar translation are chosen from a multitude sensibly fixed; and that the proportion of stationary to travelling stars rises rapidly with descent down the scale of magnitude. Hence a mean struck in disregard of the zeros is totally misleading; while the account is no sooner made exhaustive than its anomalous character becomes largely modified. Yet it does not wholly disappear. There is some warrant for it in nature. And its warrant may perhaps consist in a preponderance, among suns endowed with high physical speed, of small, or slightly luminous, over powerfully radiative bodies. Why this should be so, it would be futile, even by conjecture, to attempt to explain.

AN INGENIOUS FORGING PRESS.

MR W. D. ALLEN, in a paper read at the autumn meeting of the Iron and Steel Institute, London, in October (Nature, Oct. 15), described a forging press, which, although it has been at work for some years at the Bessemer Works in Sheffield, is so ingenious, and so new to most people, that it is worthy of description. The press has the appearance of a steam hammer, and, indeed, there is a steam cylinder at the top, just as in a hammer. The use of the steam, however, is only to raise the "tup" when the hydraulic pressure is released. The press consists of an anvil block below and a ram above, the work being in a vertical direction. The ram works in a hydraulic cylinder, and is carried through the top end of the latter in the shape of a stout shaft or shank, which may be described as a tail-rod to the ram. Attached to this is the piston rod of the steam piston, the latter, of course, working in its own cylinder. The steam cylinder and hydraulic cylinder are therefore placed tandemwise, the latter being underneath. The hydraulic cylinder is supplied with water at pressure by a suitable pump, the barrel of the pump being in direct communication with the hydraulic cylinder, there being no valve of any kind between the two.

If we have made our explanation clear, it will be seen that the ram will descend and ascend stroke for stroke with the pump plunger (the same water flowing backwards and forwards continuously), it being remembered that the steam cylinder has always a tendency to lift the ram. Thus, upon the pump making a forward stroke, the water in its barrel is forced into the hydraulic cylinder; the ram is thus forced down, and gives the necessary squeeze to the work on the anvil. The pump plunger then starts on its return stroke, and so, by enlarging the space in the pump barrel, enables the hydraulic ram to rise and press the water out of the cylinder and back into the pump. The rising of the ram is caused by the lifting action of the steam under the piston; the atter, it will be remembered, being attached to the ram. Of course the water pressure is sufficient to overcome the steam pressure on the downward stroke.

The chief use of this press is to produce work of any given thicknesses within the range of the machine. This end is attained by regulating the volume of water used. The action may be explained as follows. We will suppose, merely for simplicity sake, the contents of the pump barrel to be one cubic foot, and that of the hydraulic cylinder, when the ram is at the full extent of its stroke, to be two cubic feet. We will neglect the connecting pipe between the two, as that is not a variable and does not affect the principle. If there be admitted to the pump but one cubic foot of water as the plunger moves forward, it will drive all this water (omitting clearance) into the hydraulic cylinder, and the ram would therefore only descend one-half its stroke. If the stroke were two feet the travel would be twelve inches, whilst there would be twelve inches of space between the anvil and the lower side of the squeezing tool on the end of the ram. Objects of twelve inches, or above twelve inches in thickness, could therefore be forged. If, however, an article six inches thick had to be worked, another half cubic foot of water would have to be admitted. As the pump barrel would only accommodate one cubic foot of water, the extra half cubic foot would remain permanently in the hydraulic cylinder, and the ram would therefore not go, by six inches, to the top of its stroke; in other words, the traverse of the ram would be carried six inches nearer the anvil.

It will be remembered that the upward movement of the ram is effected by the steam cylinder, which is powerful enough to lift the dead weight of the ram, but is overcome by the hydraulic pressure. It will be seen that by regulating the volume of water in the machine, the ram — although always making the same length of stroke — can be kept working at any given distance from the anvil: the ram and pump-plunger making stroke for stroke as the water flows backwards and forwards between the barrel of the pump and hydraulic cylinder. The device is no less important than ingenious. In ordinary forging, reliance has to be placed for accuracy of work on the skill of the workman. It is surprising how near perfection a good forgeman will arrive by constant practice. Such men are necessarily scarce, and as a consequence very highly paid, but even the nearest approximation of eye and hastily applied callipers, with the chance of getting a little too much work on at the last minute, cannot equal the absolutely correct results of this automatic system.

ASTRONOMICAL NOTES.

The Rev. T. E. Espin has found two new variable stars in Cygnus, viz., D. M. + 36°, 3852, and D. M. + 49°, 3239. They are both of a strong red color.

The Harvard College Observatory has just issued a paper entitled "Preparation and Discussion of the Draper Catalogue." The introduction to the volume contains reference to the gift of Mrs. Draper of the funds by which the work has been carried on, and also a description of the instrument with which the photographs were taken. Then follows a catalogue of the spectra of the stars. The plates were exposed in the years 1886 and 1887.

In the Proceedings of the Irish Academy (vol. 4, No. 4, third series) Mr. J. E. Gore has a very interesting paper entitled "A Catalogue of Binary Stars for which Orbits have been Computed." The catalogue contains 59 stars, giving the name of each star, its approximate position for the epoch 1890.0, the elements, by whom computed, magnitude of com-